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NATIONAL RADIO ASTRONOMY OBSERVATORY

Tucson, Arizona

25 Meter Millimeter Wave Telescope
Memo #121 A

May 23, 1979

To: M. S. Roberts

From: M. A. Gordon, Project Manager, 25-m Telescope

Subj: Comparison between Mauna Kea and best mainland sites

1. Criteria for siting a millimeter-wave telescope:

Our criteria were chosen to maximize the scientific yield of the telescope. They include

a) atmospheric transparency,
b) radio environment,
c) latitude, and
d) access.

2. Atmospheric transparency:

The principal cause of variable atmospheric absorption is the amount of water vapor integrated along the line of sight. In general, water vapor decreases with altitude and toward the polar regions. Cloud cover data is not a useful index of water vapor, because the records do not distinguish transparent (for mm-waves) ice clouds from opaque water clouds.

There are two general techniques used for surveys of atmospheric water vapor: radiosondes and IR hygrometers (photometers). The photometric measurements exceed the radiosonde measurements by a factor between 1.5 and 2, after correction of the IR data for pressure-broadening effects inversely associated with altitude. The usual explanation is the presence of orographic enhancements of water vapor, which are not measured in the coarse grid of the radiosonde network. Also, the photometric surveys are daytime measurements, because these hygrometers see the sun as a source. The subsidence of high altitude air decreases with water vapor over most mountain sites at night.

The longest term survey available is the Atmospheric Humidity Atlas-Northern Hemisphere, by Gringorten et al. (1966). It is based upon 5 years of daily radiosonde flights. Most of Kuiper's work is based upon radiosonde data.

In situ photometric data is available for only a few mountain sites. These surveys usually are made with different IR water-vapor bands, in different years, and by different groups. These include surveys by Westphal and by Low. Intercomparison is difficult.

Estimates of integrated water vapor determined from ground measurements of absolute humidity appear to be unreliable for mountain sites, presumably because the vertical distribution (scale height) is uncertain and highly variable. (For example, the 4 years of available humidity measurements from Mt. Hopkins suggest water vapor levels substantially higher than observed from Kitt Peak, a lower altitude site only 100 miles away!)

While the reported levels of water vapor disagree, the relative ranking of our prime sites is generally the same from one survey to another regardless of measurement techniques.

3. Sites considered:

Based upon regional surveys and *in situ* measurements of water vapor, we considered approximately 55 sites on US soil, of which 10 were visited.

The most attractive site is Mauna Kea (Hawaii). It is dry, developed, and permits observation of most of our galaxy because of its low latitude.

The second-ranked group includes sites near Tucson: Kitt Peak, Mt. Hopkins, and Mt. Lemmon. Each has severe disadvantages compared to Mauna Kea, in addition to their reduced sky coverage due to higher latitude and shorter observing season. Kitt Peak is generally too wet for submillimeter work. The only weather data available for Mt. Hopkins suggests water vapor levels comparable to Kitt Peak, and the access road is of poor quality. Mt. Lemmon has many commercial transmitters and an army radar, located by the US Forest Service on the only site suitable for millimeter-wave astronomy.

4. Tabular data:

The following 3 tables summarize the scientific potential and costs of Mauna Kea, Mt. Lemmon, and (for comparison) our present site on Kitt Peak. Note that while the design wavelength is nominally 1.2 mm, the telescope will operate well at submillimeter wavelengths.

a) Table 1. Based upon latitude and reasonable photometric estimates of atmospheric water vapor, this table shows transmission in a number of atmospheric windows. It also shows the site's usefulness for observations of the galactic center, in the form of the equivalent observing time of this source each day, corrected for atmospheric absorption at wavelengths of 1.2 and 0.87 mm. Note that Mauna Kea is twice as effective as Kitt Peak, a third better than Mount Lemmon. Also, the summer rainy season in Tucson restricts observing to about 9 months per year, compared to the expected 12 months on Mauna Kea.

At shorter wavelengths, the difference in equivalent observing time of the galactic center increases dramatically.

b) Table 2. Environmental factors peculiar to the sites are shown.

c) Table 3. Costs of independent operation of the 25-m telescope are shown.

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Table 1

ATMOSPHERIC FACTORS

Site	Best 9 Month Daytime Water Vapor W (mm)	Zenith Atmospheric Transmission				Equivalent Galactic Center Daily Observing Time (Hours)	
		3.3 mm	1.2 mm	0.87 mm	0.73 mm	λ = 1.2 mm	λ = 0.87 mm
Mauna Kea	1.9	0.96	0.88	0.68	0.49	4.7	1.8
Mount Lemmon	2.3	0.95	0.86	0.63	0.42	3.0	0.7
Kitt Peak	3.3	0.94	0.80	0.52	0.29	1.9	0.2

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Table 3

25-M TELESCOPE COST COMPARISON
(Millions of Dollars)

Site	Construction Cost (Plan C)	Annual Operation Cost (1985)
Mauna Kea	27	3.0
Mt. Lemmon or Kitt Peak	22	1.7

Table 2

ENVIRONMENTAL FACTORS

Site	Latitude	Limiting Declinations*	Sky Coverage* $\Omega/4\pi$	Percentage Coverage* of Galactic Plane	Useful Months/Year
Mauna Kea	19°.8	-55°.2	0.91	88°	12
Mt. Lemmon	~~32.0~~ 32.5	~~-43.0~~ -42.5	0.84	80	9
Kitt Peak	32.0	-43.0	0.84	80	9

* for observations above 15° elevation

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